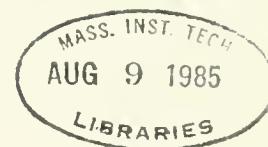




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EVALUATING OPERATING EFFICIENCY OF SERVICE
BUSINESSES WITH DATA ENVELOPMENT ANALYSIS --
EMPIRICAL STUDY OF BANK BRANCH OPERATIONS

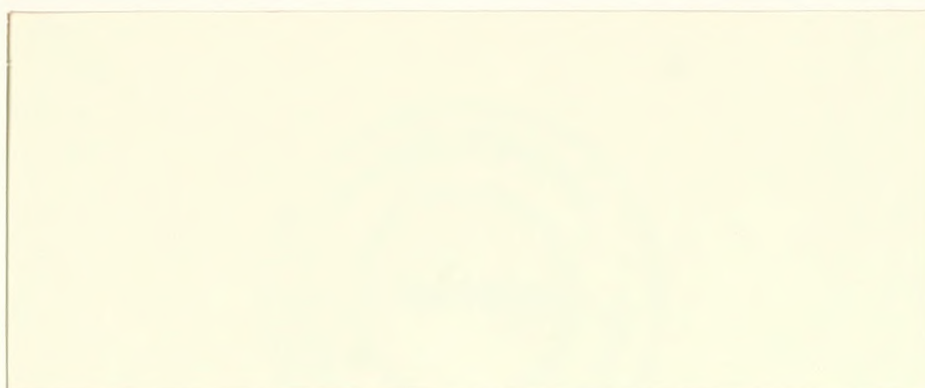
by

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Working Paper #1444-83

February, 1983

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PRIME Computer Corporation

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1. INTRODUCTION

A corporation's operating performance is frequently measured using accounting ratios such as return on sales and return on investment. These ratios provide a great deal of information about a firm's financial performance of by means of comparisons with prior years' performance and with other companies in the same industry. Nevertheless, there are limitations to the use of these measures. One is that financial ratios may fail to consider the value of management's actions and investment decisions taken with the intent of affecting future as opposed to current performance. For example, a business that defers such things as maintenance and research and development can appear to be performing well based on accounting ratios even though these actions may impair the future performance of the business. Another limitation is that accounting ratios aggregate many aspects of performance such as financing, marketing, and production. A firm may appear to be performing well even if it is poorly managed on certain of these dimensions as long as it compensates by performing particularly well on other dimensions.

Other techniques that compensate for the weaknesses in accounting ratios are needed to attain a more comprehensive evaluation of corporate performance. This paper evaluates the use of a specific new technique, Data Envelopment Analysis (DEA), which has not heretofore been used in a for profit corporate context. The results suggest that DEA can help identify and measure operating inefficiency in certain contexts where accounting ratios are either insufficient or of no help at all.

The underlying motivation for this line of research may be summarised as follows. If operating inefficiencies are reliably identified, management can use this information to improve operating efficiency and profits regardless of

how well the organization appears to be performing based on other techniques like financial ratios.

Bank Branch Performance Evaluation Problems

Savings bank branch offices were selected as a test site for this study because it is one example of a situation where accounting ratios were insufficient for performance evaluation. Other examples of the types of performance evaluations that may be possible with this technique will be discussed in the concluding section of this paper.

Management of a savings bank with 14 branches indicated that it used various accounting measures to assess the profitability of each branch. The primary measure used was constructed as follows:

Branch profit = Interest revenues on funds generated by the branch

- Service fee revenues
- Cost of funds generated by the branch (mostly interest)
- operating costs including personnel, materials, and rent.

The profit as calculated above could, of course, be normalized across branches by calculating the return on investment (profit ÷ average investment in the branch) and profit as a percent of interest and service fee revenues. These and other accounting ratios were useful in characterizing the source and trend of accounting profits. Nevertheless, these ratios have several inherent limitations when used to evaluate performance as described below.

1. Funds generated from a savings account at one branch were frequently deposited and processed in another branch. Hence, the cost of processing the funds may be incurred by a branch that will get no recognition for having generated these funds while the operating costs of that branch will reflect the processing cost. The above profit measure will, therefore, penalize the branch that processes funds for another branch's account.
2. A particular branch may have accounts which have many non-fund generating transactions such as withdrawals or savings bond purchases. The profitability of such a branch may appear lower even though it provides a service which is necessary to maintain the accounts within the bank.
3. A branch may have higher operating costs and lower profitability because the mix of transactions requires greater resources, e.g., issuing a savings bond requires more processing time than accepting a savings deposit.

In the above three examples, a branch which is measured as having lower profits may not be performing less efficiently than the apparently more profitable branches. Hence, use of a profit measure to evaluate a branch's operating efficiency, i.e., resources used to operate the branch may be incomplete or misleading. A comprehensive evaluation of bank branch performance, therefore, requires the use of other operating performance measures in addition to the profit measure and related financial ratios.

Each branch uses a set of inputs or resources to jointly provide a set of services and to generate funds. What is missing in the profit measure is the ability to evaluate how efficiently the resources are being used in providing these services. One approach to this problem is to calculate the cost per transaction (operating costs ÷ total number of transactions). This has the virtue of considering the cost of a transaction as distinct from the amount of funds generated or withdrawn in each transaction. Here again there are at least two weaknesses.

- a. The mix of transactions are not considered so that the branch with more complex and more resource consuming transactions may appear to be less efficient than one with less complex transactions.

- b. The use of dollar cost of inputs may bias the evaluation. For example, different branches will have varying rates of pay which may be a result of the average employees' years of service and not the amount of labor hours consumed. A branch with higher average employee years of service may appear to be less efficient than one with fewer years of service if cost per transaction is used as a measure of operating efficiency.

The problems noted above arise because there are multiple outputs (services and/or transactions) provided with multiple inputs. One approach to circumvent these problems and more directly evaluate the operating efficiency of a branch might be to estimate the efficient time and material resources required for each transaction, i.e., develop a classical cost accounting standard [1]. The extent to which each branch exceeds the standard (efficient) amount of resources needed to process its volume and mix of transactions would be a measure of its operating inefficiency. At this point, we acknowledge this alternative and note that such standards have not been developed for savings bank transactions.

This paper explores another alternative—Data Envelopment Analysis (DEA)—as a means of evaluating operating efficiency of a set of savings bank branches. DEA was initially developed by Charnes, Cooper and Rhodes ([4], [5], and [6]) to evaluate the efficiency of public sector and nonprofit organization where accounting profit measures are of little value and where multiple outputs are produced with multiple inputs but the efficient or standard input-output relationships are not easily identified. Our objective, is to assess applicability of DEA in the corporate setting via a field application to a set of bank branches.

The following section describes the characteristics of DEA and the procedure required to apply it to savings bank branches. Section 3 describes the savings banks and the process of identifying the outputs and inputs for the DEA evaluation. Section 4 reports the results of the DEA evaluation of the branches. In concluding section 5, we consider how DEA can most effectively be used for bank branch evaluations and describe other for-profit organizations that seem most likely to benefit from the use of DEA as a tool for performance evaluation.

2. Data Envelopment Analysis Characteristics and Procedures

DEA is a linear programming technique that evaluates the relative efficiency of a set of organizations in their use of multiple inputs to produce multiple outputs. It achieves this result by comparing the set of organizations' observed outputs and inputs, and identifies a subset of organizations that are relatively inefficient (and the magnitude of the inefficiencies) compared to the other units in the observation set.

A brief description of DEA in the appendix.¹

DEA has been shown to provide the following types of results in evaluating organizations.

¹ In addition, the technique is described in detail in [5] [6] and [7] and tests of the technique are described in [8] and [13]. Examples of other nonprofit applications of DEA include hospitals [14], court systems [11], and educational institutions [4].

1. Each unit being evaluated will have a derived efficiency rating of $E = 1$ which implies relatively efficient or $E < 1$ which implies relatively inefficient. If $E < 1$, the unit is strictly inefficient compared to other units in the observation set. If $E = 1$, the unit is not necessarily strictly efficient but this indicates that it was not found to be less efficient than other units in the observation set. Hence, DEA is primarily of interest to find units rated as inefficient. An inefficient unit is defined as one which should be able to produce the same output levels it provided with fewer inputs than it actually used compared with actual operations of other units in the observation set.
2. DEA will identify the subset of units, the efficiency reference set against which the inefficient unit was most directly compared to calculate the efficiency rating. Thus DEA compares each unit in the observation set with all the other units but in its final output, it allows one to focus on only a subset of the units to understand the location and nature of the inefficiency.
3. While DEA provides information on alternative paths that would make an inefficient unit relatively efficient, management must select the path which is most feasible.

Hence, DEA can compare organizations with multiple outputs and inputs and identify inefficient units, their efficiency reference sets, and alternative paths to make the unit relatively efficient. These characteristics will be illustrated in the application to the savings bank branches. The type of organizations that can be compared with DEA and requirements to apply DEA are discussed below.

Organizations that are to be evaluated with DEA must produce the same kinds of outputs with the same type of inputs. Hence, one can compare savings bank branches within a bank or across banks as long as they provide a similar range of services with similar inputs.

Output and Input data

The data required to apply DEA is a measure of each of the relevant outputs and of each of the inputs used to produce these outputs. Relevant outputs would include those services that management believes are basic to the purpose of the organization, i.e., those services that a branch manager is expected to provide to customers. The inputs should reflect the resources that are required to produce the outputs such that an increase/decrease in output levels is expected to result in an increase/ decrease in the amount of inputs required. Ideally, the outputs and inputs should be measured in physical units. In many cases, dollar units may be the only available unit measure. When dollar units are used, it is important to recognize that the DEA efficiency rating will not necessarily distinguish inefficiency arising from use of excessive amounts of resources from inefficiency due to paying excessively high prices for similar inputs.

To use DEA, it is sufficient to identify and measure the relevant outputs and inputs. It is not necessary to specify the relationship of how these inputs are used to produce these outputs, i.e., the efficient production function. DEA is used to determine which units produce these outputs least efficiently with the inputs used.

3. Savings bank branch Outputs and Inputs

Banking literature reflects two distinct schools of thought about the nature of a bank's outputs: liquidity versus the account. The liquidity definition of a bank's outputs suggests that the funds generated on the stock of deposits is the primary output as this is the primary source of income, i.e., revenues generated on funds less the cost of these funds. The liquidity

view of outputs appears to dominate because it is basic to the economics of banking. A bank's primary business is to generate funds from customers and lend or invest these funds at a yield that exceeds the cost of these funds. If a bank is unable to do this, the efficiency with which they process account transactions will be a moot issue. Goldschmidt directly argues for the liquidity view which he refers to as "moneyness" and states that it represents the "more important activities of banks" [9]. (Benston [3], and Gorman [10] also discuss the liquidity point of view.) Nevertheless, Goldschmidt also points out that liquidity is a limited measure of output. In concluding his article Goldschmidt states that "for other purposes (especially for specific types of bank cost studies) alternative definition of output may be found more suitable". Note that for the liquidity dimension of bank outputs, financial accounting ratios are a suitable technique for evaluating bank performance.

The other view of bank outputs discussed by Mackara [10] and Benston [3] defines the account and related transaction as the relevant unit of measure. This view is justified because the major costs associated with operating a bank arise from servicing accounts. Benston notes that "Output Mix is usually a serious problem for cost studies, since the pressure of joint costs make it difficult to estimate the costs of specific outputs". Gorman indicates that the account view is also closely related to the liquidity view in that "the costs involved in facilitating transactions--check cashing, bookkeeping, etc--become intermediate costs that the banks are forced to assume in making the deposits liquid enough for depositors to hold them".

For purposes of this study, it is sufficient to note that both the liquidity and the account output definitions are relevant to bank performance and that we will emphasize the account (or production) view since there already exist reasonable accounting measures to address the liquidity performance dimension.

The output measure used in this study is the number of transactions of each type processed by the branch. Number of transactions rather than number of accounts are used because deposits in any one branch do not necessarily become deposits in that branch, (as the account may have been opened at another branch). In addition, the transaction volume more directly determines the resources required to maintain a branch than the number of accounts, since all accounts are not equally active with equally complex transactions.

The output measure selected was developed in coordination with bank management by listing all the services that were considered to be of value to a customer. These services were then categorized into four levels of difficulty (Dif 1, . . . Dif 4) corresponding to the levels of resources required to process a transaction. For this bank, management noted seventeen different services which they categorized into the four difficulty levels noted in Table 1. These were reduced to four groups because management believed the distinctions in resource levels within groups would be insignificant. It was not necessary to judge or estimate the magnitude of resource consumption that separates each set of transactions. All that is needed for DEA is to measure the number of transactions in each group as will be illustrated in the results section that follows.

Input identification

Inputs in banking are not unlike those of other firms in that they consist primarily of labor, capital, and materials (Bell and Murphy [2]).

The inputs used in this study were labor, occupancy costs, and supply costs. The data for labor were based on a measure of full-time equivalent workers per branch. The wages for these employees was not considered for reasons already explained. Included in this full-time equivalent measure are tellers, customer service representatives,

Table 1

Service Output		DEA Output measure	
1	Loan Applications		(Most
2	New Passbook Loans	Dif 1	resource
3	Life Insurance Sales		consuming)
4	New Accounts		
5	Closed Accounts	Dif 2	
6	Travelers Checks Sold		
7	Bonds Sold	Dif 3	
8	Bonds redeemed		
9	Deposits		
10	Withdrawals		
11	Checks cashed		
12	Treasury checks issued		(least
13	B5 checks	Dif 4	resource
14	Loan payments		consuming)
15	Passbook Loan payments		
16	Life Insurance payments		
17	Mortgage payments		

and the branch management.

The space used for each branch (in square feet) was not available. The closest available substitute was the rent paid for each branch. There may be some difficulty with using rent in the analysis. Rent will vary due to the desirability of locations. This will, in turn, affect the traffic pattern, customer mix, and types of services requested. However, the use of square feet to measure the input of facilities is also not a perfect measure. Available floor space will differ as a percentage of total floor space for each branch. Also, the layout of the floor plan will affect the ability and efficiency of the workers in handling customer transactions. Many factors relating to space cannot be easily quantified and, therefore, rent, which captures some of these non-quantifiable factors, was used as an input approximation.

Supply inputs were measured using the total cost of supplies used. Supplies cannot be easily grouped due to the different units involved (amount of stationery, stamps, etc.). Therefore, the cost of supplies is used as a substitute for actual supplies used. This should not alter the validity of the measure of efficiency, although introduction of costs does move the analysis away from a strict measure of physical input-output efficiency. All the branches were located in the same metropolitan area and followed similar purchasing guidelines so the issue of different cost levels, i.e., price inefficiency was believed by management to be an insignificant issue.

4. DEA Evaluation of Bank Branches - Results and Analysis

The DEA results are summarized in Table 2 for the 14 bank branches. Data for each branches' four outputs and three inputs for a one-year period was used for the DEA evaluation. These data are reproduced in Appendix 2.

Interpretation of DEA Results

Based on the data provided on the outputs and inputs, DEA identified six of the fourteen branches to be relatively inefficient as reported in table 2. Each branch with an efficiency rating of less than 1.0 in Table 2 is relatively inefficient: BR5, BR7, BR8, BR11, BR12, and BR13. The efficiency rating is not a strict rank ordering but rather suggests the degree of inefficiency a branch has compared to its efficiency reference set as determined by DEA. Hence, BR5 is about 90% efficient compared to BR 2, BR4, and BR6. BR13 is also about 90% efficient but compared with BR2 and BR14. In this case, both BR5 and BR13 should be able to reduce each of their input levels by about 10% without reducing their output levels to be as efficient as their respective efficiency reference sets. Similarly, BR7 has the lowest efficiency rating of 78% which means it would have to reduce its inputs by 22% to become as efficiency as its reference set of BR2, BR3, and BR6.

DEA provides additional insights about the magnitude of the inefficiency beyond the simple identification of inefficient units and their efficiency reference set. In Table 3 the amount of inefficiency identified for BR12 compared with its efficiency reference set of BR3, BR6, and BR10 is shown. This suggests that BR12 provided less service, in terms of number of transactions, and used more inputs than the composite of the reference set. If BR12 could adopt a mixture of operating techniques used in the reference set of branches, it should be able to provide at least the current level of service while using fewer inputs, which would result in a lower cost of operations and increased profitability.

Table 2

Branch Code	DEA Efficiency Rating...	Efficiency Reference Set	Non-personnel operating expense per transaction	Transactions processed per full time equi- valent employee (in thousands)
(1)	(2)	(3)	(4)	(5)
BR1	1.0		\$0.0298	177.96
BR2	1.0		0.0156	318.71
BR3	1.0		0.0135	345.33
BR4	1.0		0.0235	338.18
BR5	0.904	BR2, BR4, BR6	0.0347	327.16
BR6	1.0		0.0192	437.85
BR7	0.782	BR2, BR3, BR6	0.0262	311.89
BR8	0.987	BR2, BR3, BR6,		
		BR9	0.0165	351.33
BR9	1.0		0.0187	403.81
BR10	1.0		0.0161	351.82
BR11	0.967	BR2, BR6, BR14	0.0230	331.25
BR12	0.853	BR3, BR6, BR10	0.0232	229.88
BR13	0.905	BR2, BR14	0.0388	281.47
BR14	1.0		0.0253	361.27

Table 3

Branch 12 compared with its efficiency reference set Branches 3, 6, and 10

	Branch 12 vs. actual outputs and inputs	Derived Composite of efficiency reference set branches 3, 6, and 10(a)	Excess inputs and deficient outputs of B12 vs. BR3, BR6, and BR10
	(A)	(B)	(C) = (A) - (B)
<u>Outputs (# of transactions in thousands)</u>			
Dif 1	94	168.43	74.43
Dif 2	511	518.12	7.12
Dif 3	26.96	26.95	-0-
Dif 4	2304.01	2303.0	-0-
			} deficient out- puts of BR12 compared with BR3, BR6, and BR10
<u>Inputs</u>			
Rent in thousands of dollars	42.3	36.11	6.2
Full time equivalent personnel	8.9	7.6	1.3
Supplies in thousands of dollars	25.8	17.6	8.2
			} excess inputs of BR12 compared with composite of BR3, BR6, and BR10.

(a) This composite is a linear combination of the actual outputs and inputs of Branches 3, 6, and 10 which is derived by multiplying the inputs and outputs of each Branch by the shadow price resulting from the DEA linear program results (see [7] and [12] for further details). The Branches with a non-zero shadow price are the efficiency reference set. In linear programming terms these are the basis vectors that yield the efficiency ratings in Table 2. For BR12, the composite is as follows:

	Shadow price for BR3 from DEA	Output Input vector of BR3	Shadow price BR6 from DEA	Output input vector of BR6	Shadow price if BR10 from DEA	Output input vector of BR10	Composite input/ output of efficiency reference set
<u>Outputs</u>							
Dif 1		209		272		72	168.43
Dif 2		1058.9		776.4		402.5	518.12
Dif 3	(.034) x	65.7	(.492) x	34.8	(.382) x	19.9	26.95
Dif 4		3570.0		2660.0		2284.9	2303.0
<u>Inputs</u>							
Rentals		36.6		50.8		25.7	36.1
FTE's		14.2		8.3		7.9	7.6
Supply \$s		29.8		18.9		19.0	17.6

These results were further analyzed and discussed with management of the bank and the following conclusions emerged.

- (1) Of the six branches identified as inefficient, management noted that the highly inefficient branch BR7 was already earmarked for termination because it was already viewed as marginal due to its proximity to another branch and its low profitability based on liquidity criteria. Of the other inefficient branches, four were believed to be run by weaker managers and the DEA result was consistent with management's perceptions. Management was surprised to find one highly profitable branch had been identified as inefficient. They had planned to review that and the other four branches' operations to understand what types of efficiency improvements are possible.
- (2) Two of the branches identified as inefficient were the smallest in terms of transactions, (BR5, BR13) and none of the five largest branches was identified as inefficient. Two explanations for these small branch inefficiencies were offered:
 1. There were diseconomies of scale at low transaction volumes particularly with respect to personnel since a branch must have one manager and at least one teller.
 2. Less experienced managers were assigned to small branches.

Further investigation of the source of these inefficiencies was completed by considering two types of ratios, number of transactions per FTE and nonpersonnel cost per transaction (reported in Table 2). Scale economies with respect to labor usage did not seem to explain the inefficiency, since BR% processed more transactions than larger branches, BR2 and BR7. With respect to nonpersonnel cost per transaction, the smallest branches BR5 and BR13 were the most costly, suggesting scale economies with respect to these inputs.

The key points to note is that in contrast to DEA, the use of these other ratios in table 2 do not take the transaction mix into account and may, therefore, be misleading. In addition, they do not explicitly identify inefficient branches. There are numerous different ratios that might be developed but there is no objective method of combining these different ratios for an assessment of inefficiency as was possible with DEA.

- (3) Management acknowledged that the process of identifying the outputs and inputs and the DEA results helped focus on the operating aspects of the branches as distinct from the liquidity based profitability measures. Motivated by the DEA results, management indicated that the service outputs and the resources used to provide these would be further evaluated as distinct from the liquidity issues.

5. Conclusions and Future Uses of DEA in a Corporate Applications

DEA appears to provide useful insights which are not available from other performance measures that are largely oriented toward profitability assessment and based on other operating ratios. Specifically, DEA can explicitly consider the mix of outputs and inputs and identify units which are inefficient and which can, therefore, produce the same level of outputs with fewer inputs. A unit that is found to be inefficient can potentially become more profitable by reducing input levels (and related costs) regardless of how profitable that unit appears to be using financial ratio criteria. Furthermore, DEA helps focus on the location and magnitude of the inefficiency present. In short, DEA provided insights relevant to managing a business not available from ratio analysis.

Where then is DEA most appropriately utilized and what types of organization fit into that category?

DEA appears to be most useful in a for profit environment when the following characteristics are present.

- (1) The organization jointly produces a multiple set of outputs with multiple inputs. Ratio analysis is generally not adequate for performance evaluation because it fails to consider the mix of the outputs and inputs.
- (2) The efficient output-input relationships are not known or easily identified. In a manufacturing environment where the efficient cost of an output is known based on engineered standards, there are more direct means such as variance analysis for evaluating efficiency and DEA is not needed. DEA is most useful for service type outputs where the standard or efficient cost is not easily calculated.
- (3) DEA can only be used to compare relative efficiency among a set of entities which produce similar outputs and inputs. Consequently, DEA would be most readily applied to an organization which has multiple units providing similar services where management has an interest in comparing and improving performance across these offices.

In addition to savings bank branches, there are a large class of organizations which meet the above three criteria. Examples of organizations that may benefit from use of DEA are as follows:

- Commercial bank branches where the outputs would differ from savings bank branches but the problem structure might be very similar.
- Customer service organizations, providing repairs, maintenance, and other services related to a firm's products, e.g., computer hardware, insurance claims offices.
- Multi-office professional service organizations such as a CPA firm.

The key limitations of DEA in corporate applications include the following:

- (1) DEA can only locate relatively efficient units compared with other similar units. It could be used to compare operations across competing companies as is done in the non-profit sectors with organizations such as hospitals, where much of the data required is public information. In the corporate sector, however, such data will tend to be unavailable. Hence, DEA will be applicable primarily where a single corporate entity has the need to compare performance among its multiple offices providing similar services.
- (2) DEA accurately locates relatively inefficient units but it cannot necessarily locate all the inefficient units. Indeed, all the units being evaluated with DEA may have inefficiencies which can be remedied but DEA can only locate those units which are inefficient compared to the more efficient units in the data set. This means that inefficiencies located with DEA will tend to be understated rather than overstated. Compensating for this limitation is DEA's ability to direct management to those units with distinct and real inefficiencies which are likely to benefit from remedial action.

Extended use of DEA

In addition to comparing operating efficiency for a specified time frame as was done for the bank branches in this study, DEA can be used in other ways in corporate settings. Examples of these alternatives follow.

- (a) Sensitivity analysis -- DEA can be used to complete "what if" analyses to determine, for example, if the paths selected by management to improve the efficiency of an inefficient unit would make that unit relatively efficient (see for example [13]). Another

example of this is the savings bank in the study planned to acquire another bank with several branches and management proposed use of DEA to evaluate the operations of the new branches compared with their existing branches.

- (b) Dynamic evaluation -- A set of time periods of actual operations such as a number of quarters or years for a group of units can be evaluated with DEA to determine whether units are becoming more or less efficient over time. This would of course require filtering out business cyclicity where this impacts the output levels of the various units.

Future Directions for Research

The usefulness of DEA results in directing the attention of management to inefficient operating units has been positively received in the nonprofit sector and in this pilot application to the for-profit sector. The use of DEA results as a basis for effecting real improvements in operating efficiency and the management process required to achieve this requires further investigation. Such studies should be designed to clarify the ways managers should respond to the DEA information to develop and implement programs to improve operating efficiency.

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Appendix — Exhibit 1

The DEA Model

DEA measures the efficiency of bank branch o compared with the n branches in the data set as follows:

Objective:

$$\max E_o = \frac{\sum_{r=1}^s u_r y_{ro}}{\sum_{i=1}^m v_i x_{io}}$$

where o is the bank branch being evaluated in the set of $j = 1, \dots, n$ bank branches. (This analysis is run repetitively with each bank branch in the objective function to derive an efficiency rating for each of the n branches).

Constraints:

$$\begin{array}{ll} \text{Less than} & s \\ \text{Unity} & : 1 > \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} ; j = 1, \dots, n \end{array} \quad (1)$$

Constraints

$$\begin{array}{ll} \text{Positivity} & : 0 < u_r ; r = 1, \dots, s \\ \text{Constraints} & : 0 < v_i ; i = 1, \dots, m \end{array}$$

Data:

Outputs: y_{rj} = observed amount of r^{th} output for the j^{th} bank branch

Inputs: x_{ij} = observed amount of i^{th} input for the j^{th} bank branch

The data used for each bank branch are the y_{rj} outputs; and the x_{ij} inputs. The u_r , v_i values are determined from the data by the above model. DEA provides an ex post evaluation of how efficient each bank branch was with the actual inputs (x_{ij}) used to produce its outputs (y_{rj}) without explicit knowledge of the input-output relationships it used. The weights in the form of the u_r and the v_i are not known or given a priori. They are, instead, calculated as (u_r , v_i) values to be assigned to each input and output in order to maximize the efficiency rating $--E_o^*$ of the bank branch being evaluated. That is, the solution sought is the set of (u_r , v_i) values that will give the bank branch being rated the highest

efficiency ratio, E_o^* , but not result in an input-output ratio exceeding 1 (100% efficiency) when applied to any and all other bank branches in the data set. (See [5] and [7] for further details).

Applying DEA to a set of bank branches results in an efficiency rating for each branch of 1 (relatively efficient) or less than 1 (relatively inefficient). These ratings, however, represent relative efficiencies based on comparison of branches in the data set ($j = 1 \dots n$ branches). A bank branch that is found to be inefficient ($h_o < 1$) is strictly inefficient compared to other bank branches in the data set as is shown in [13].

Note that the u_r , v_i values calculated by DEA are objectively determined weights which may not correspond to relative values that a bank branch would assign to outputs and inputs. This is actually a strength and not a weakness of DEA. A bank branch located as efficient using DEA is so identified only after all possible weights have been considered to give that bank branch the highest rating possible consistent with the constraint that no bank branch in the data set can be more than 100% efficient. Hence, any other set of weights applied to all bank branches would only make an inefficient bank branch appear less efficient, i.e., DEA gives the benefit of the doubt to each bank branch in calculating the efficiency value.

The DEA evaluation also provides insights far beyond the identification of the inefficient bank branches (see [14]) as is illustrated in the bank branch application in table 3 and further described in [14].

Appendix -- Exhibit 2

Output-Input Data for Savings Bank Branches

<u>Branch #</u>	<u>DIF1</u>	<u>DIF2</u>	<u>DIF3</u>	<u>DIF4</u>	<u>RENT</u>	<u>FTE's</u>	<u>Supplies</u>
#1	484.000	4139.100	59.860	2951.430	-140.000	-42.900	-87.500
#2	384.000	1685.500	139.780	3336.860	-48.800	-17.400	-37.900
#3	209.000	1058.900	65.720	3570.050	-36.600	-14.200	-29.800
#4	157.000	879.400	27.340	2081.350	-47.100	-9.300	-26.800
#5	46.000	370.900	18.920	1069.100	-32.600	-4.600	-19.600
#6	272.000	667.400	34.750	2660.040	-50.800	-8.300	-18.900
#7	53.000	465.700	20.240	1800.250	-40.800	-7.500	-20.400
#8	250.000	642.700	43.280	2296.740	-31.900	-9.200	-21.400
#9	407.000	647.700	32.360	1981.930	-36.400	-7.600	-21.000
#10	72.000	402.500	19.930	2284.910	-25.700	-7.900	-19.000
#11	105.000	482.400	49.320	2245.160	-44.500	-8.700	-21.700
#12	94.000	511.000	26.960	2304.010	-42.300	-8.900	-25.800
#13	84.000	287.400	34.940	1141.750	-40.600	-5.500	-19.400
#14	199.000	694.600	67.160	3338.390	-76.100	-11.900	-32.800

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Date Due

OCT 20 1985
AUG. 31 1985

Lib-26-67

Date Due

SE 15 '88

SE 14 '89

OCT 2 1989

BASEMENT

BASEMENT

